Supporting Comprehensive Foods for Health Research: A New Model

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I will focus my discussion on three areas:

- twenty-first century biology,
- the enormous challenges that are facing us, and
- new models for partnerships.

TWENTY-FIRST CENTURY BIOLOGY

Isn't twenty-first century biology the same as twentieth century biology? More than 10 years ago, Alan Bromley, Science Advisor to the elder Bush, made this statement: "If this century is the age of physics"—and he's a physicist—"the twenty-first century will be the age of biology." You have probably heard that from many people since. President Clinton talked about the twenty-first century being the age of biology. Al Gore thought he invented it. But when Bromley made the statement more than 10 years ago, we hadn't seen the sequencing of the human genome. Sequencing the *Arabidopsis* genome was just something that people imagined might be possible. Fantastic things happened during the last decade of the twentieth century, and the *Arabidopsis* genome is a particular achievement because it is the first eukaryote to be fully sequenced. I mean *completely*, because the human genome is still in rough draft and is not scheduled to be finished until 2003.

Twenty-first century biology is very different from the biology of even a few years ago. It is multi-disciplinary. Teams of scientists are working together and will continue to work together. Physicists, mathematicians, computer scientists, and social scientists: all are focusing on the major questions in biology that will be solved, I think, in this century.

Twenty-first century biology is also multi-dimensional. For the first 50 years of the biological revolution, *i.e.* since the elucidation of the structure of DNA by Watson and Crick, biology was mainly reductionist, whereas with the new technologies and new disciplines we will be able to put all of the pieces together and address questions from the atomic level through the ecosystem level even to the planetary level.

It is also information-driven. Enormous quantities of data are being produced and it is commonplace for scientists to "mine" databases like Genbank. New hypotheses are being derived from sequence data—a capability that was unimaginable a few years ago.

And, it is education-oriented because we need a new kind of scientist to work on these problems—one who is comfortable in a multi-disciplinary team setting, and that is different from the biology of several years ago.

And twenty-first century biology engages people internationally. Geographic boundaries no longer inhibit scientists. Because of the Internet we have what Jack Marburger, President Bush's Science Advisor, called the power of a "global intelligence" to draw upon. Sometimes people find it easier to exchange ideas and data across the globe than to walk down the hall and talk with a colleague.

SIX MAJOR CHALLENGES

Boxology Major challenges are associated with advancing twenty-first century biology, which really isn't biology, it's twenty-first century *science*. I see six major challenges, the biggest of which is to overcome twentieth-century barriers. A colleague of mine calls this "boxology" because we all work in boxes; we have to get outside of these boxes and think about the larger picture. These boxes exist everywhere. They certainly exist in my agency, the National Science Foundation (NSF), in which we have directorates, the Mathematics and Physical Sciences Directorate, the Biology Directorate, *etc*. Do we talk across those boundaries? Yes we do, but it's a huge challenge because of differing cultures. You see this in universities. Certainly departmental barriers exist that work against interdisciplinary research. Think about tenure decisions. Tom Czeck talked to the National Science Board a week or so ago and said that he was appalled recently at a committee meeting in which a faculty member was being considered for tenure, and the question was asked, "How many times has this person's name appeared first on a paper?" Even though the person had published lots of papers, the name had not appeared first on many of them. Yet when you look at journals today, especially with these multidisciplinary projects, like the *Arabidopsis* genome project or the human genome project, you will see long lists of names. What happens to the person whose name is in the middle? In some journals a statement is made that all the authors contributed equally. What do tenure committees do with that kind of information? It is an academic barrier that has to be overcome in some way.

Federal agency barriers exist not just at NSF. The Office of Management and

Budget, where the budgets of the agencies are determined, exists in compartments because the budget examiners focus on each agency separately. They hardly ever coordinate across agencies. Only with cross-cutting efforts like the global climate change project do they bring agency representatives together to talk about coordinating budgets.

Broadening Participation A second major challenge is in broadening participation. It is essential that we tap the diversity in human resources in the United States. It is a national scandal that we have not been able to increase the participation of underrepresented minorities in science. But it is more than underrepresented minorities. More and more students are opting out of science—a recent report showed that 50% of undergraduates who major in science drop out within the first couple of years. The major cause is not poor grades but that courses aren't interesting—the curriculum fails to engage the student largely because of lack of faculty interest.

To broaden participation we must include diverse institutions, including community colleges where many minority students get their start. Some 46% of underrepresented minorities attend community colleges, so we at the NSF are putting a lot of emphasis on including *all* colleges and the tribal colleges. It is a major challenge.

Reshaping Education A third challenge relates to reshaping the education of scientists and engineers to broaden the horizons of students who are interested in majoring in science and engineering. Some of the programs that we support at NSF, like the IGERT Traineeship Program, are exciting because students and faculty work in multidisciplinary teams. We also think that postdocs need to have a number of options. They should have the opportunity to teach, therefore we are changing our postdoctoral programs at NSF to allow a semester or a year to gain teaching experience. There should be possibilities for graduate students and postdocs to have internships in industry, which we have not allowed until now. And finally, all of them need international experience, which is essential for the future.

Public Perceptions My fourth major challenge is public understanding of science. A recent survey indicated broad popular acceptance internationally that solar energy and computers will improve our lives. As for genetic engineering, however, a sizeable number of people expressed the conviction that it will make things worse, similar to attitudes on nuclear power. This is something that requires much thought, and foods for health should go a long way to improving public perceptions of agricultural biotechnology.

Infrastructure The next major challenge is infrastructure and research facilities. Costs of maintaining cyber-infrastructure—instrumentation, security, *etc*.—are going to skyrocket for universities. In 1998, research-one universities issued a report in which the cost of maintaining facilities, not including upgrading with the new technology, was estimated at over $11 billion. Clearly, the NSF cannot address this issue alone. In fact, the whole federal government will have trouble meeting this challenge.

Funding My final major challenge is funding—something that I know a lot about. In an NSF publication, *Science and Engineering Indicators*, published in May 2002, it was shown that the federal government supplied 66% of the funds for R&D in 1960, whereas in 2000 industry supplied 72% and the federal government only 28%. But, the 72% supplied by industry in 2000 was mainly the "D" part of R&D—development of products. Only 5% of that 72% was invested in fundamental research and the 28% provided by the federal government was almost entirely for fundamental research and some applied research. In short, industry will not replace the federal government's support for fundamental research.

From 1967 to 2000, the United States Department of Agriculture (USDA) and NSF grant funds were pretty flat in constant dollars. In contrast, federal funding for Health and Human Services, which goes mostly to the National Institutes of Health (NIH), has grown and is still growing, and will have doubled by 2003 at over $27 billion. When I say that NSF needs a big increase, people sometimes say, "Take it out of the Farm Bill." However, we don't want to take money away from any other agency. The NIH can use their increased funding very profitably—there is no suggestion that we want to transfer money from NIH to any other agency. We need increased overall investment in research by the federal government. Less than $350 million—not billion—were invested by the government in competitive grants in plant biology in 2001. Clearly we have a long way to go to reach adequate funding for twenty-first century biology.

New Partnerships

How are we going to meet these challenges? We need new kinds of partners. We need effective partnerships involving private and public sectors. State governments should also be involved and we need international partners.

In 1997, it was decided that we needed a long-term plan for plant genomics, which was clearly a promising area. Under the leadership of Ron Phillips, an interagency working group was established with a 5-year plan. The first thing that we recommended was to complete the sequencing of *Arabidopsis*, which has happened. We will hold a stakeholders' workshop at the National Academy on June 6 and 7, 2002, to plan the next 5 years.

The interagency national plant-genome initiative involves the NSF, the Department of Energy (DOE), the NIH, and the USDA. As already stated, the first priority was to sequence model-plant species, then we addressed the research resources that would be needed, the databases, the kinds of technology development that needed to occur and, very importantly, data management and informatics. In fact we now insist on an informatics component in all of the projects in plant genomics now funded by NSF. So *Arabidopsis*-genome sequencing was completed. The first completely sequenced plant genome—found to have about 25,000 genes—was published in 2000 as a result of a successful international partnership. Japan and the European Union were involved, as was France in its own right through Genoscope. And, in the United States, NSF, USDA and DOE all supported the effort. One of my guiding principles for international projects is that each country pays its own way so that it feels that it is a full partner, and this happened beautifully with *Arabidopsis*—there were no problems. But, as I have said before, the reason for such great cooperation was probably that there was no money to be made.

Next we said that rice needed to be sequenced, because the genes of rice are very similar to those in all of the grasses. Corn has a rather larger genome, about the size of the human genome. We are receiving suggestions from the corn community that it should be sequenced next, and then wheat.

The international rice genome project was another interesting partnership as a new model of international collaboration. The members of that team are from Korea, China, Taiwan, Thailand, India, the United Kingdom, France, and Brazil. Japan is the lead nation, but China is catching up fast. China has sequenced *Oryza indica*, whereas Japan and the other partners are sequencing *O. japonica*. It is noteworthy that Monsanto provided data that was useful in completing the rice genome project. The data are being deposited in Genbank and will be publicly available. Discussions are going on now with Syngenta. I would like to think that companies will cooperate with the federal government and private and public sources to produce the kind of model that will work for us in the future.

We are coordinating well on a couple of other projects. In the microbe project we are doing everything we can to build the infrastructure, to connect the dots, to learn as much as we can. This interagency working group involves the CIA, FBI, Department of Defense, the Food and Drug Administration (FDA), and NASA, *etc*. Our goal is to build the necessary infrastructure to learn as much as we can about microbes, 99% of which have received little, if any, study. Only a few that are pathogenic to humans have been thoroughly studied—even then we have learned over the past few months how much we don't know about anthrax.

Recently the National Academy held a workshop on domestic-animal genomics, the result of which is an inter-agency working group that is chaired by Joe Jen the Undersecretary for Research, Education and Economics at the USDA. They are just getting started, discussing what kinds of sequencing need to be done, *etc*., related to animal genomics.

The 2010 Project is another that involves international collaboration to determine the function of all of the genes in *Arabidopsis*. It began last year and we hope it will be completed by 2010. All of the 2010 Project reports are available on the Internet. Another international collaborative activity is the USEC task force on biotechnology research, which was established in 1990 as a forum for discussion of new ideas. A Blue Sky Workshop—predicting what biotechnology would look like 20 to 25 years from now—was in session on September 11, 2001, in Washington, DC, and was rescheduled for June 2003 in Brussels.

In closing, I will reiterate that we need new kinds of partnerships for twenty-first century biology. Now only scratching the surface, we need involvement of the public sector, the states and local government as well as the federal government, because we cannot do it alone.[1]

[1]The Q&A session with Dr. Clutter is on p. 185.